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GB 2242527 A **GB 1311585 A** **EP 0254445 A1**

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(54) Tyre mileage monitoring apparatus and method

(57) A tyre mileage monitoring device comprises a transducer unit 5 mounted adjacent a periphery of a tyre 1 of a vehicle to provide an electrical signal representative of mechanical forces acting on the tyre during its rotation, and signal processing means which receives the transducer signal and provides an output signal representative of changes in the mechanical forces acting on the periphery of the tyre as a result of the peripheral region adjacent the transducer unit coming into contact with the ground. As described the transducer is a piezoelectric device mounted on the internal surface of the tyre or embedded in its fabric, and the processor comprises a pulse generator and a counter.

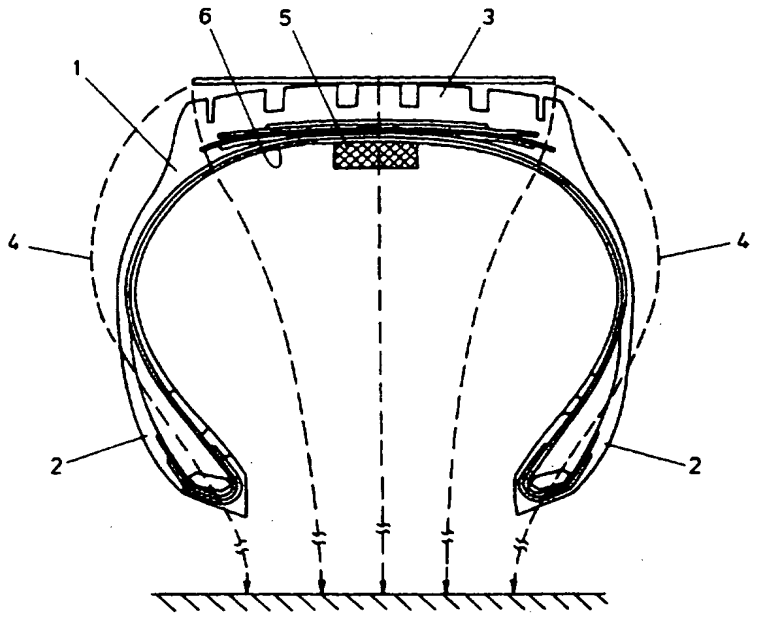

FIG. 1

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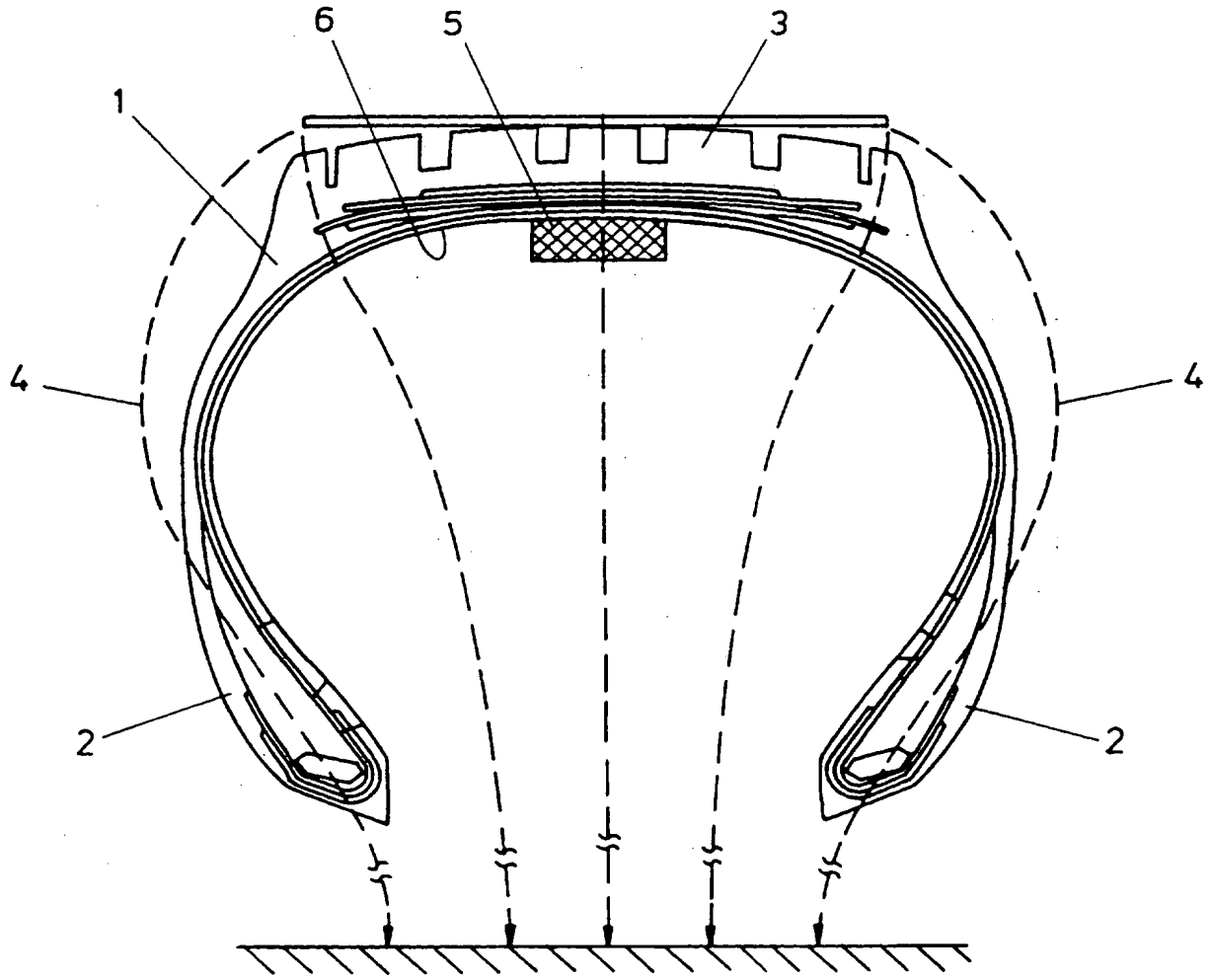

FIG. 1

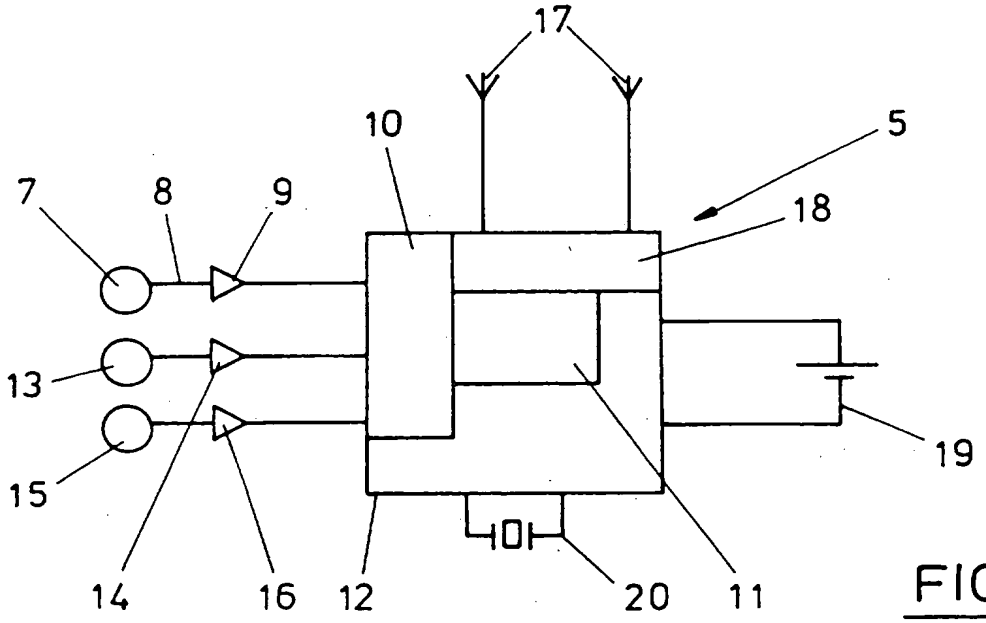

FIG. 2

TYRE MILEAGE MONITORING APPARATUS AND METHOD

The present invention relates to a method and apparatus for monitoring tyre mileage and relates particularly, but not exclusively, to an apparatus and method for monitoring tyre mileage of heavy goods vehicles.

When hazardous materials are transported by road in heavy goods vehicles, tyre failure can have very serious consequences. Whilst warning in advance of potential tyre failure is often provided by carrying out regular tyre maintenance, recent improvements in the safety and reliability of heavy goods vehicle tyres has resulted in vehicle users taking tyre reliability for granted and overlooking regular maintenance.

Mileage sensors are known which are connected to the gear box of a vehicle and provide an indication of the mileage travelled by the vehicle. Such conventional mileage detectors suffer from the disadvantage, however, that an indication is only provided of the mileage travelled by the vehicle as a whole, and no indication is given of the mileage travelled by individual tyres. This causes particular problems when individual wheels of a heavy goods vehicles are replaced, such that the various wheels of the vehicle have different mileages.

It is an object of the present invention to provide more reliable monitoring of tyre mileage.

According to an aspect of the present invention, there is provided a tyre mileage monitoring device, the device comprising:-

a mechanical transducer mounted in use adjacent the periphery of a tyre of a vehicle, for providing an electrical output signal representative of mechanical forces acting on the periphery of the tyre during rotation thereof; and

signal processing means for receiving the output signal of the mechanical transducer and providing an output signal representative of changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

By mounting a mechanical transducer directly to a tyre of

the vehicle, this provides the advantage of more directly monitoring the number of revolutions of that tyre of the vehicle, as opposed to the gear box of the vehicle, and the mileage of the tyre can be monitored even if the tyre is removed from that vehicle and mounted to a different vehicle.

The mechanical transducer may comprise a piezoelectric crystal for generating a voltage dependent upon mechanical forces acting on the crystal.

The mechanical transducer may be mounted to an internal peripheral surface of the tyre.

Alternatively, the mechanical transducer may be embedded within the tyre.

Alternatively, the mechanical transducer may be mounted to a side wall of the tyre.

In a preferred embodiment of the invention, the signal processing means comprises a pulse generator for generating a series of electrical pulses, each of which represents a change in the mechanical forces acting on the periphery of the tyre, as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

The signal processing means may further comprise a counter for counting said electrical pulses.

In this way, the signal processing means can be constructed in a particularly simple and convenient manner for digital processing by, for example a micro-processor.

The pulse generator may comprise a CMOS circuit.

This provides the advantage of low power consumption of the pulse generator.

The signal processing means may further comprise an analogue / digital converter, and said pulse counter may comprise a shift register.

Preferably, the signal processing means further comprises a micro-processor for processing the output of pulse counter and collating data relating to the number of revolutions rotated by the tyre.

The signal processing means may provide an output representative of a number of revolutions rotated by the tyre.

Data may be periodically collated by the micro-processor, each collation period corresponding to a plurality of revolutions of the tyre.

By only collating data periodically for a large number of revolutions, this provides the advantage of reducing power consumption of the device.

The output signal of the signal processing means may include an identification code unique to the tyre.

In this way, confusion between the outputs of monitoring devices mounted to different tyres of a vehicle can be minimised.

The device may further comprise radio frequency transmitter means for transmitting the output signal of the signal processing means to a remote station.

This provides the advantage of enabling data to be automatically down loaded and analysed at the remote station, such as a heavy goods vehicle depot.

The device may further comprise radio frequency receiver means for enabling the device to be interrogated from a remote station.

This has the advantage of enabling the output means to remain dormant until activated by the remote station via the radio frequency receiver means.

In a preferred embodiment, transmission of the output signal of the signal processing means is activated by interrogation of the device via the radio frequency receiver means from the remote station.

The device may further comprise pressure sensor means for providing an electrical output signal representative of the pneumatic pressure in the tyre, wherein the output signal of the pressure sensor means is supplied to the signal processing means.

This provides the advantage of enabling the pressure to be monitored in addition to the mileage travelled by the tyre so that optimum fuel consumption can be achieved, and slow punctures can be detected. It also provides the advantage of giving prior warning of catastrophic tyre failure.

The pressure sensor means may include a piezoelectric element.

The device may further comprise temperature sensor means for providing an electrical output signal representative of the temperature of the tyre, wherein the output signal of the temperature sensor means is supplied to the signal processing means.

This provides the advantage of detecting high temperatures of the tyre body, either during use or during re-processing (such as re-treading) which often gives advance warning of catastrophic tyre failure.

The device as defined above may be included in single transponder unit adapted to be mounted in use adjacent the periphery of the tyre.

This provides the advantage of a particularly compact construction, and enables the transponder unit to be conveniently mounted to the tyre during manufacture.

According to another aspect of the present invention, there is provided a system for monitoring mileage of individual tyres of a vehicle, the system comprising a plurality of devices as defined above, and display means for receiving the output signal of the signal processing means of each said device and displaying mileage travelled by each tyre of the vehicle.

The display means may be a computer.

The display means may be remote from the vehicle.

According to a further aspect of the invention, there is provided a method of monitoring mileage of a vehicle tyre, the method comprising:

providing a mechanical transducer adjacent the periphery of a tyre for producing an electrical output representative of mechanical forces acting on the periphery of the tyre adjacent the transducer during rotation thereof; and

detecting changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground; and

providing an electrical output signal representative of the number of revolutions rotated by the tyre.

The step of detecting changes in the mechanical forces acting on the periphery of the tyre may comprise generating electrical pulses representative of the changes in mechanical forces, and counting said pulses.

The method may further comprise the step of periodically collating the output signal representative of the number of revolutions stated, wherein a period of collation may correspond to several such revolutions.

In a preferred embodiment, the method further comprises providing in the output signal an identification code unique to the tyre.

The method may further comprise the step of transmitting said output signal via a radio frequency transmitter to a remote station.

The method may further comprise a step of initiating transmission of said output signal from a remote station via a radio frequency receiver.

The method may further comprise the step of monitoring the pressure in said tyre.

The method may further comprise the step of monitoring the temperature of said tyre.

For a better understanding of the invention, a preferred embodiment of the invention will now be described in detail below, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:-

Figure 1 is a cross-sectional view of a tyre incorporating a transponder unit embodying an aspect of the present invention; and

Figure 2 is a detailed schematic view of the transponder unit of Figure 1.

Referring in detail to Figure 1, the rubber body of a tyre 1 is shown in cross-section in bold lines, the tyre 1 having side walls 2 and tread region 3. The external shape taken up by the side walls of the tyre 1 when in contact with the ground (not shown) is indicated by dotted lines 4.

A transponder unit 5 is mounted at a central region of an internal peripheral wall 6 of the tyre 1 by any suitable means during manufacture of the tyre, such as fixing by means of adhesive. Alternatively, the transponder may be embedded within the peripheral wall 6 or mounted to one of the side walls 2 internally thereof.

Referring now to Figure 2, the transponder 5 comprises a mechanical detector 7 for producing an electrical output signal representative of mechanical forces acting on the transponder unit 5 when the tyre 1 is rotating. The sensor 7 comprises a piezoelectric crystal of dimensions of the order of 2mm x 5mm mounted within an enclosure and having a pair of wires (not shown) attached thereto, such that when the piezoelectric crystal is subjected to forces, a voltage is generated across the two wires which is dependent upon (e.g. generally proportional to) the forces acting on the piezoelectric crystal.

The output of sensor 7 is connected to a CMOS pulse generating circuit 8 which generates a series of electrical pulses, each of which indicates a change in mechanical forces acting on the sensor 7 as a result of the periphery of the tyre 1 adjacent thereto coming into contact with the ground during rotation of the tyre 1. By using a CMOS circuit 8, power consumption of the circuit 8 is minimised. The electrical output of sensor 7 has two constituent parts, a first part representing forces acting on the sensor 7 due to the random but continuous vibrations within the structure of the tyre 1 as the tyre rotates, and a second part which results from a large mechanical impulse each time the periphery of the tyre 1 in the vicinity of the transponder 5 contacts the ground. This mechanical impulse produces a significant voltage pulse which is distinguishable by means of circuit 8 from the general background noise level, such that circuit 8 produces a stream of pulses from its output, each pulse representing a single revolution of tyre 1. The random but continuous vibrations within the structure of tyre 1 as tyre 1 rotates produces a continuous background voltage noise level which can be used to

provide energy to power suitable drive circuitry (not shown) for sensor 7, for example by means of charging a suitable capacitor arrangement.

The output signal provided by circuit 8 is supplied to an analogue / digital converter 9, which is in turn connected to a micro-processor 10. The micro-processor 10 has memory 11 which includes a CMOS shift register and a counter. The memory 11 of micro-processor 10 also includes an identity code unique to the tyre 1, the function of which will be described below.

A pressure sensor 14 comprises a piezoelectric resistance element of dimensions of the order of 3mm x 3mm, rigidly mounted within an enclosure. The pressure sensor 14 is a constant current device and is a 4 terminal device with resistors in a bridge arrangement, such that changes in ambient pressure within the tyre 1 cause corresponding changes in resistance of the piezoelectric element. The constant current is fed through two of the terminals of sensor 14 and the voltage difference across the other two terminals of the sensor 14 are fed into two inputs (not shown) of a differential amplifier 15, the output of which is fed to analogue / digital converter 9. The pressure sensor 14 is calibrated at ambient pressure such that when the sensor 14 is subjected to an external pressure, the piezoelectric element exhibits a change in resistance which is detected at the output.

A temperature sensor 16 comprises a resistance bridge in which the temperature co-efficient of resistance is accurately known at room temperature and is used to detect changes in temperature of the body of tyre 1 and / or of the air within the tyre 1 adjacent to the transponder 5. The output of sensor 16 is fed via amplifier 17 to the analogue / digital converter 9.

The transponder unit 5 also includes a coil antenna 18 for transmission and receipt of radio frequency signals to and from a remote station (not shown), the antenna 18 being connected to the microprocessor 10 via input / output circuitry 19. The micro-processor 10 is powered by means of a battery 19, and the timing pulses of micro-processor 10 are generated

by a crystal oscillator 13. In addition to providing power via battery 12, the voltage and / or current output provided by one or more of sensors 7, 14, 16 may be used to drive the analogue / digital converter 9 and memory 11.

The operation of the apparatus shown in Figures 1 and 2 will now be described.

A transponder 5 is mounted to each tyre 1 of a heavy goods vehicle (not shown) and a remote station (not shown) communicating with transponder unit 5 by means of radio frequency signals through antenna 18 is mounted at a suitable road side location, such as the gate of a heavy goods vehicle depot. The remote station is designed to communicate with the transponder unit 5 over a distance of the order to 1.5 metres to 3 metres. This enables the remote station to communicate with the transponder 5 at low frequency, which generally does not necessitate special permits.

As the heavy goods vehicle exits or re-enters the depot and passes the remote station, the memory 11 of micro-processor 10 is re-set by means of a radio frequency signal from the remote station through antenna 18 to the micro-processor 10. The sensors 7, 14, 16 then begin to produce output signals representative of the number of revolutions, pressure, and temperature respectively of the tyre 1 subsequently to the vehicle leaving the depot. These signals pass via circuits 8, 15, 17 respectively to analogue / digital converter 9 and are stored in shift register (not shown) of memory 11 of micro-processor 10. When the shift register is full, or at a suitable interval such as 1000 revolutions of the tyre 1, the number of counts stored in the shift register is transferred to the micro-processor 10 for integration and summation such that collated data on the mileage, pressure and temperature of the tyre 1 is stored in memory 11 of the micro-processor 10.

When the vehicle returns to the depot, an interrogation signal is transmitted from the remote station to the transponder 5 via antenna 18. This causes battery 12 to energise transponder 5 to transmit data stored in the memory 11 of the micro-processor 10 via antenna 18 back to the remote

station, where it may be stored in a computer or otherwise displayed. The data transmitted from memory 11 also includes an identity code unique to each transponder 5 to avoid confusion between signals transmitted from the different tyres 1 of the heavy goods vehicle. In this way, the micro-processor 10 remains dormant until activated by the remote station when the vehicle returns to the depot, thus saving power of battery 12.

It can therefore be seen that the apparatus of Figures 1 and 2 provides a convenient system for monitoring mileage, pressure and temperature of the tyres of a heavy goods vehicle. The system is still useful for monitoring tyre conditions even if the tyre is removed from a vehicle and mounted to another vehicle.

It will be appreciated by persons skilled in the art that the above embodiment has been described by way of example only and for the purpose of illustration, and not in any limitative sense, and that various alterations and modifications of the system are possible without departure from the scope of the invention as defined by the appended claims.

CLAIMS:

1. A tyre mileage monitoring device, the device comprising:-

a mechanical transducer mounted in use adjacent the periphery of a tyre of a vehicle, for providing an electrical output signal representative of mechanical forces acting on the periphery of the tyres during rotation thereof; and

signal processing means for receiving the output signal of the mechanical transducer and providing an output signal representative of changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

2. A device according to claim 1, wherein the mechanical transducer comprises a piezoelectric crystal for generating a voltage dependant upon mechanical forces acting on the crystal.

3. A device according to claim 1 or 2, wherein the mechanical transducer is mounted to an internal peripheral surface of the tyre.

4. A device according to claim 1 or 2, wherein the mechanical transducer is embedded within the tyre.

5. An apparatus according to claim 1 or 2, wherein the mechanical transducer is mounted to a side wall of the tyre.

6. A device according to any one of the preceding claims, wherein the signal processing means comprises a pulse generator for generating a series of electrical pulses, each of which represents a change in the mechanical forces acting on the periphery of the tyre, as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

7. A device according to claim 6, wherein the signal processing means further comprises a counter for counting said electrical pulses.

8. A device according to claim 6 or 7, when the pulse generator comprises a CMOS circuit.

9. A device according to any one of claims 6 to 8,

wherein the signal processing means further comprises an analogue / digital converter, and said pulse counter comprises a shift register.

10. A device according to any one of claims 6 to 9, wherein the signal processing means further comprises a microprocessor for processing the output of the pulse generator and collating data relating to the number of revolutions rotated by the tyre.

11. A device according to claim 1, wherein the signal processing means provides an output representative of a number of revolutions rotated by the tyre.

12. A device according to claims 10 and 11, wherein the signal processing means in use periodically collates data, each collation period corresponding to a plurality of revolutions of the tyre.

13. A device according to any one of the preceding claims, wherein the output signal of the signal processing means includes an identification code unique to the tyre.

14. A device according to any one of the preceding claims, further comprising radio frequency transmitter means for transmitting the output signal of the signal processing means to a remote station.

15. A device according to any one of the preceding claims, further comprising radio frequency receiver means for enabling the device to be interrogated from a remote station.

16. A device according to claims 14 and 15, wherein transmission of the output signal of the signal processing means is activated by interrogation of the device via the radio frequency receiver means from the remote station.

17. A device according to any one of the preceding claims, further comprising pressure sensor means for providing an electrical output signal representative of the pneumatic pressure in the tyre, wherein the output signal of the pressure sensor means is supplied to the signal processing means.

18. A device according to claim 17, wherein said pressure sensor means includes a piezoelectric element.

19. A device according to any one of the preceding

claims, further comprising temperature sensor means for providing an electrical output signal representative of the temperature of the tyre, wherein the output signal of the temperature sensor means is supplied to the signal processing means.

20. A device according to any one of the preceding claims, wherein the device is included in a single transponder unit adapted to be mounted in use adjacent the periphery of the tyre.

21. A system for monitoring mileage of individual tyres of a vehicle, the system comprising a plurality of devices according to any one of the preceding claims, and display means for receiving the output signal of the signal processing means of each said device and displaying mileage travelled by each tyre of the vehicle.

22. A system according to claim 21, wherein the display means comprises a computer.

23. A system according to claim 21 or 22, wherein the display means is remote from the vehicle

24. A method of monitoring mileage of a vehicle tyre, the method comprising:

providing a mechanical transducer adjacent the periphery of a tyre for producing an electrical output representative of mechanical forces acting on the periphery of the tyre adjacent the transducer during rotation thereof; and

detecting changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground; and

providing an electrical output signal representative of the number of revolutions rotated by the tyre.

25. A method according to claim 24, wherein the step of detecting changes in the mechanical forces acting on the periphery of the tyre comprises generating electrical pulses representative of the changes in mechanical forces, and counting said pulses.

26. A method according to claim 24 or 25, further

comprising the step of periodically collating the output signal representative of the number of revolutions rotated by the tyre, wherein a period of collation corresponds to a plurality of revolutions.

27. A method according to any one of claims 24 to 26, further comprising the step of providing in the output signal an identification code unique to the tyre.

28. A method according to any one of claims 24 to 27, further comprising the step of transmitting the output signal via a radio frequency transmitter to a remote station.

29. A method according to claim 28, further comprising the step of initiating said transmission of said output signal from a remote station via a radio frequency receiver.

30. A method according to any one of claims 24 to 29, further comprising the step of monitoring the pressure in said tyre.

31. A method according to any one of claims 24 to 30, further comprising the step of monitoring the temperature of said tyre.

32. A tyre mileage monitoring device substantially as hereinbefore described with reference to the accompanying drawings.

33. A tyre mileage monitoring system substantially as hereinbefore described with reference to the accompanying drawings.

34. A tyre mileage monitoring method, substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9522808.6
Relevant Technical Fields (i) UK Cl (Ed.N) G1N (NACNC, NACNN, NAFD10, NAFDR, NAHJA, NAHJD) (ii) Int Cl (Ed.6) G01C 22/00, 22/02	Search Examiner MR G CLARKE Date of completion of Search 18 DECEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1 to 34

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	**P:**	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	**E:**	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	**&:**	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2242527 A	(GEC-MARCONI LTD) whole document	
A	GB 1311585	(THE BENDIX CORPN) whole document	
A	EP 0254445 A1	(PHILIP E. GALASKO) whole document	

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(54) Tyre mileage monitoring apparatus and method

(57) A tyre mileage monitoring device comprises a transducer unit 5 mounted adjacent a periphery of a tyre 1 of a vehicle to provide an electrical signal representative of mechanical forces acting on the tyre during its rotation, and signal processing means which receives the transducer signal and provides an output signal representative of changes in the mechanical forces acting on the periphery of the tyre as a result of the peripheral region adjacent the transducer unit coming into contact with the ground. As described the transducer is a piezoelectric device mounted on the internal surface of the tyre or embedded in its fabric, and the processor comprises a pulse generator and a counter.

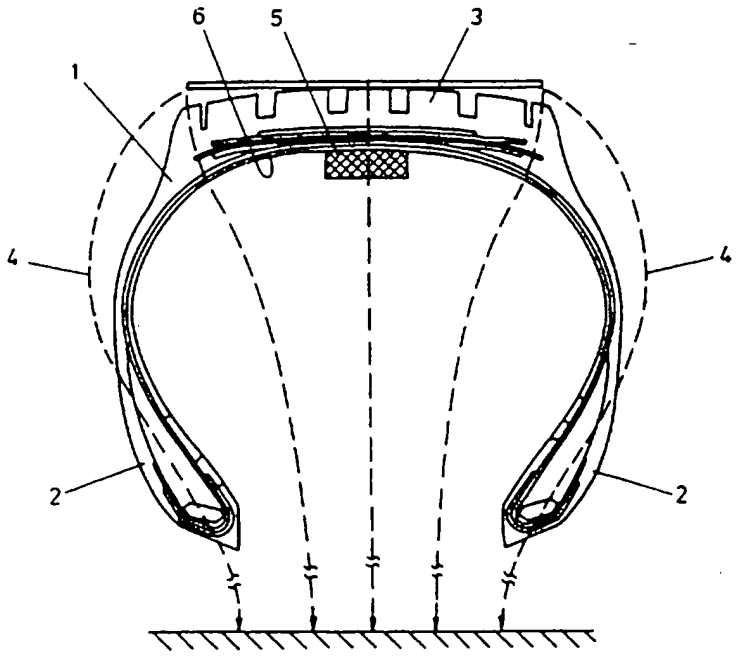

FIG. 1

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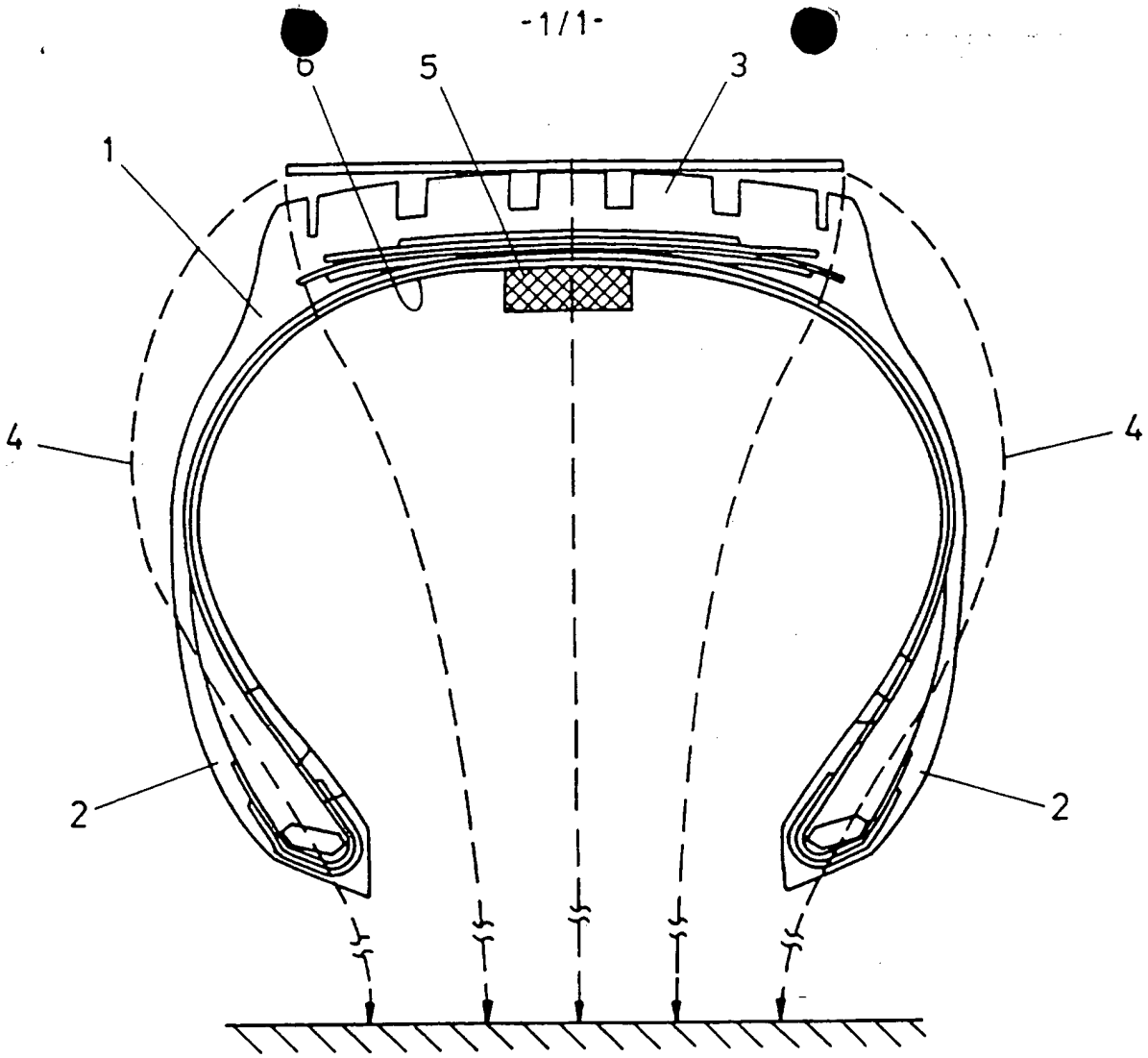

FIG. 1

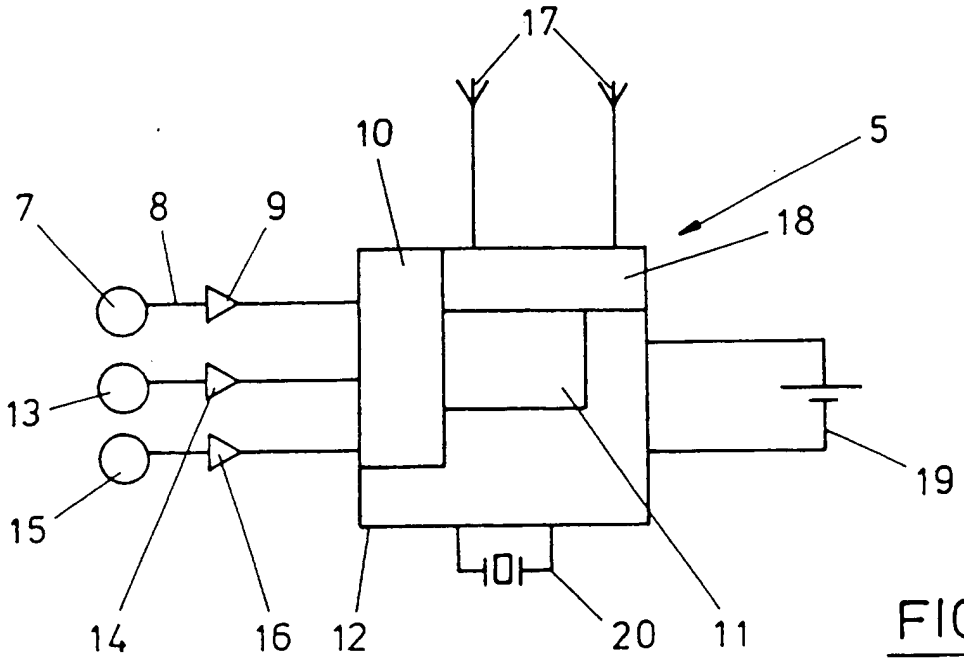

FIG. 2

TYRE MILEAGE MONITORING APPARATUS AND METHOD

The present invention relates to a method and apparatus for monitoring tyre mileage and relates particularly, but not exclusively, to an apparatus and method for monitoring tyre mileage of heavy goods vehicles.

When hazardous materials are transported by road in heavy goods vehicles, tyre failure can have very serious consequences. Whilst warning in advance of potential tyre failure is often provided by carrying out regular tyre maintenance, recent improvements in the safety and reliability of heavy goods vehicle tyres has resulted in vehicle users taking tyre reliability for granted and overlooking regular maintenance.

Mileage sensors are known which are connected to the gear box of a vehicle and provide an indication of the mileage travelled by the vehicle. Such conventional mileage detectors suffer from the disadvantage, however, that an indication is only provided of the mileage travelled by the vehicle as a whole, and no indication is given of the mileage travelled by individual tyres. This causes particular problems when individual wheels of a heavy goods vehicles are replaced, such that the various wheels of the vehicle have different mileages.

It is an object of the present invention to provide more reliable monitoring of tyre mileage.

According to an aspect of the present invention, there is provided a tyre mileage monitoring device, the device comprising:-

a mechanical transducer mounted in use adjacent the periphery of a tyre of a vehicle, for providing an electrical output signal representative of mechanical forces acting on the periphery of the tyre during rotation thereof; and

signal processing means for receiving the output signal of the mechanical transducer and providing an output signal representative of changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

By mounting a mechanical transducer directly to a tyre of

the vehicle, this provides the advantage of more directly monitoring the number of revolutions of that tyre of the vehicle, as opposed to the gear box of the vehicle, and the mileage of the tyre can be monitored even if the tyre is removed from that vehicle and mounted to a different vehicle.

The mechanical transducer may comprise a piezoelectric crystal for generating a voltage dependent upon mechanical forces acting on the crystal.

The mechanical transducer may be mounted to an internal peripheral surface of the tyre.

Alternatively, the mechanical transducer may be embedded within the tyre.

Alternatively, the mechanical transducer may be mounted to a side wall of the tyre.

In a preferred embodiment of the invention, the signal processing means comprises a pulse generator for generating a series of electrical pulses, each of which represents a change in the mechanical forces acting on the periphery of the tyre, as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

The signal processing means may further comprise a counter for counting said electrical pulses.

In this way, the signal processing means can be constructed in a particularly simple and convenient manner for digital processing by, for example a micro-processor.

The pulse generator may comprise a CMOS circuit.

This provides the advantage of low power consumption of the pulse generator.

The signal processing means may further comprise an analogue / digital converter, and said pulse counter may comprise a shift register.

Preferably, the signal processing means further comprises a micro-processor for processing the output of pulse counter and collating data relating to the number of revolutions rotated by the tyre.

The signal processing means may provide an output representative of a number of revolutions rotated by the tyre.

Data may be periodically collated by the micro-processor, each collation period corresponding to a plurality of revolutions of the tyre.

By only collating data periodically for a large number of revolutions, this provides the advantage of reducing power consumption of the device.

The output signal of the signal processing means may include an identification code unique to the tyre.

In this way, confusion between the outputs of monitoring devices mounted to different tyres of a vehicle can be minimised.

The device may further comprise radio frequency transmitter means for transmitting the output signal of the signal processing means to a remote station.

This provides the advantage of enabling data to be automatically down loaded and analysed at the remote station, such as a heavy goods vehicle depot.

The device may further comprise radio frequency receiver means for enabling the device to be interrogated from a remote station.

This has the advantage of enabling the output means to remain dormant until activated by the remote station via the radio frequency receiver means.

In a preferred embodiment, transmission of the output signal of the signal processing means is activated by interrogation of the device via the radio frequency receiver means from the remote station.

The device may further comprise pressure sensor means for providing an electrical output signal representative of the pneumatic pressure in the tyre, wherein the output signal of the pressure sensor means is supplied to the signal processing means.

This provides the advantage of enabling the pressure to be monitored in addition to the mileage travelled by the tyre so that optimum fuel consumption can be achieved, and slow punctures can be detected. It also provides the advantage of giving prior warning of catastrophic tyre failure.

The pressure sensor means may include a piezoelectric element.

The device may further comprise temperature sensor means for providing an electrical output signal representative of the temperature of the tyre, wherein the output signal of the temperature sensor means is supplied to the signal processing means.

This provides the advantage of detecting high temperatures of the tyre body, either during use or during re-processing (such as re-treading) which often gives advance warning of catastrophic tyre failure.

The device as defined above may be included in single transponder unit adapted to be mounted in use adjacent the periphery of the tyre.

This provides the advantage of a particularly compact construction, and enables the transponder unit to be conveniently mounted to the tyre during manufacture.

According to another aspect of the present invention, there is provided a system for monitoring mileage of individual tyres of a vehicle, the system comprising a plurality of devices as defined above, and display means for receiving the output signal of the signal processing means of each said device and displaying mileage travelled by each tyre of the vehicle.

The display means may be a computer.

The display means may be remote from the vehicle.

According to a further aspect of the invention, there is provided a method of monitoring mileage of a vehicle tyre, the method comprising:

providing a mechanical transducer adjacent the periphery of a tyre for producing an electrical output representative of mechanical forces acting on the periphery of the tyre adjacent the transducer during rotation thereof; and

detecting changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground; and

providing an electrical output signal representative of the number of revolutions rotated by the tyre.

The step of detecting changes in the mechanical forces acting on the periphery of the tyre may comprise generating electrical pulses representative of the changes in mechanical forces, and counting said pulses.

The method may further comprise the step of periodically collating the output signal representative of the number of revolutions stated, wherein a period of collation may correspond to several such revolutions.

In a preferred embodiment, the method further comprises providing in the output signal an identification code unique to the tyre.

The method may further comprise the step of transmitting said output signal via a radio frequency transmitter to a remote station.

The method may further comprise a step of initiating transmission of said output signal from a remote station via a radio frequency receiver.

The method may further comprise the step of monitoring the pressure in said tyre.

The method may further comprise the step of monitoring the temperature of said tyre.

For a better understanding of the invention, a preferred embodiment of the invention will now be described in detail below, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:-

Figure 1 is a cross-sectional view of a tyre incorporating a transponder unit embodying an aspect of the present invention; and

Figure 2 is a detailed schematic view of the transponder unit of Figure 1.

Referring in detail to Figure 1, the rubber body of a tyre 1 is shown in cross-section in bold lines, the tyre 1 having side walls 2 and tread region 3. The external shape taken up by the side walls of the tyre 1 when in contact with the ground (not shown) is indicated by dotted lines 4.

A transponder unit 5 is mounted at a central region of an internal peripheral wall 6 of the tyre 1 by any suitable means during manufacture of the tyre, such as fixing by means of adhesive. Alternatively, the transponder may be embedded within the peripheral wall 6 or mounted to one of the side walls 2 internally thereof.

Referring now to Figure 2, the transponder 5 comprises a mechanical detector 7 for producing an electrical output signal representative of mechanical forces acting on the transponder unit 5 when the tyre 1 is rotating. The sensor 7 comprises a piezoelectric crystal of dimensions of the order of 2mm x 5mm mounted within an enclosure and having a pair of wires (not shown) attached thereto, such that when the piezoelectric crystal is subjected to forces, a voltage is generated across the two wires which is dependent upon (e.g. generally proportional to) the forces acting on the piezoelectric crystal.

The output of sensor 7 is connected to a CMOS pulse generating circuit 8 which generates a series of electrical pulses, each of which indicates a change in mechanical forces acting on the sensor 7 as a result of the periphery of the tyre 1 adjacent thereto coming into contact with the ground during rotation of the tyre 1. By using a CMOS circuit 8, power consumption of the circuit 8 is minimised. The electrical output of sensor 7 has two constituent parts, a first part representing forces acting on the sensor 7 due to the random but continuous vibrations within the structure of the tyre 1 as the tyre rotates, and a second part which results from a large mechanical impulse each time the periphery of the tyre 1 in the vicinity of the transponder 5 contacts the ground. This mechanical impulse produces a significant voltage pulse which is distinguishable by means of circuit 8 from the general background noise level, such that circuit 8 produces a stream of pulses from its output, each pulse representing a single revolution of tyre 1. The random but continuous vibrations within the structure of tyre 1 as tyre 1 rotates produces a continuous background voltage noise level which can be used to

provide energy to power suitable drive circuitry (not shown) for sensor 7, for example by means of charging a suitable capacitor arrangement.

The output signal provided by circuit 8 is supplied to an analogue / digital converter 9, which is in turn connected to a micro-processor 10. The micro-processor 10 has memory 11 which includes a CMOS shift register and a counter. The memory 11 of micro-processor 10 also includes an identity code unique to the tyre 1, the function of which will be described below.

A pressure sensor 14 comprises a piezoelectric resistance element of dimensions of the order of 3mm x 3mm, rigidly mounted within an enclosure. The pressure sensor 14 is a constant current device and is a 4 terminal device with resistors in a bridge arrangement, such that changes in ambient pressure within the tyre 1 cause corresponding changes in resistance of the piezoelectric element. The constant current is fed through two of the terminals of sensor 14 and the voltage difference across the other two terminals of the sensor 14 are fed into two inputs (not shown) of a differential amplifier 15, the output of which is fed to analogue / digital converter 9. The pressure sensor 14 is calibrated at ambient pressure such that when the sensor 14 is subjected to an external pressure, the piezoelectric element exhibits a change in resistance which is detected at the output.

A temperature sensor 16 comprises a resistance bridge in which the temperature co-efficient of resistance is accurately known at room temperature and is used to detect changes in temperature of the body of tyre 1 and / or of the air within the tyre 1 adjacent to the transponder 5. The output of sensor 16 is fed via amplifier 17 to the analogue / digital converter 9.

The transponder unit 5 also includes a coil antenna 18 for transmission and receipt of radio frequency signals to and from a remote station (not shown), the antenna 18 being connected to the microprocessor 10 via input / output circuitry 19. The micro-processor 10 is powered by means of a battery 19, and the timing pulses of micro-processor 10 are generated

by a crystal oscillator 13. In addition to providing power via battery 12, the voltage and / or current output provided by one or more of sensors 7, 14, 16 may be used to drive the analogue / digital converter 9 and memory 11.

The operation of the apparatus shown in Figures 1 and 2 will now be described.

A transponder 5 is mounted to each tyre 1 of a heavy goods vehicle (not shown) and a remote station (not shown) communicating with transponder unit 5 by means of radio frequency signals through antenna 18 is mounted at a suitable road side location, such as the gate of a heavy goods vehicle depot. The remote station is designed to communicate with the transponder unit 5 over a distance of the order to 1.5 metres to 3 metres. This enables the remote station to communicate with the transponder 5 at low frequency, which generally does not necessitate special permits.

As the heavy goods vehicle exits or re-enters the depot and passes the remote station, the memory 11 of micro-processor 10 is re-set by means of a radio frequency signal from the remote station through antenna 18 to the micro-processor 10. The sensors 7, 14, 16 then begin to produce output signals representative of the number of revolutions, pressure, and temperature respectively of the tyre 1 subsequently to the vehicle leaving the depot. These signals pass via circuits 8, 15, 17 respectively to analogue / digital converter 9 and are stored in shift register (not shown) of memory 11 of micro-processor 10. When the shift register is full, or at a suitable interval such as 1000 revolutions of the tyre 1, the number of counts stored in the shift register is transferred to the micro-processor 10 for integration and summation such that collated data on the mileage, pressure and temperature of the tyre 1 is stored in memory 11 of the micro-processor 10.

When the vehicle returns to the depot, an interrogation signal is transmitted from the remote station to the transponder 5 via antenna 18. This causes battery 12 to energise transponder 5 to transmit data stored in the memory 11 of the micro-processor 10 via antenna 18 back to the remote

station, where it may be stored in a computer or otherwise displayed. The data transmitted from memory 11 also includes an identity code unique to each transponder 5 to avoid confusion between signals transmitted from the different tyres 1 of the heavy goods vehicle. In this way, the micro-processor 10 remains dormant until activated by the remote station when the vehicle returns to the depot, thus saving power of battery 12.

It can therefore be seen that the apparatus of Figures 1 and 2 provides a convenient system for monitoring mileage, pressure and temperature of the tyres of a heavy goods vehicle. The system is still useful for monitoring tyre conditions even if the tyre is removed from a vehicle and mounted to another vehicle.

It will be appreciated by persons skilled in the art that the above embodiment has been described by way of example only and for the purpose of illustration, and not in any limitative sense, and that various alterations and modifications of the system are possible without departure from the scope of the invention as defined by the appended claims.

CLAIMS:

1. A tyre mileage monitoring device, the device comprising:-

a mechanical transducer mounted in use adjacent the periphery of a tyre of a vehicle, for providing an electrical output signal representative of mechanical forces acting on the periphery of the tyres during rotation thereof; and

signal processing means for receiving the output signal of the mechanical transducer and providing an output signal representative of changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

2. A device according to claim 1, wherein the mechanical transducer comprises a piezoelectric crystal for generating a voltage dependant upon mechanical forces acting on the crystal.

3. A device according to claim 1 or 2, wherein the mechanical transducer is mounted to an internal peripheral surface of the tyre.

4. A device according to claim 1 or 2, wherein the mechanical transducer is embedded within the tyre.

5. An apparatus according to claim 1 or 2, wherein the mechanical transducer is mounted to a side wall of the tyre.

6. A device according to any one of the preceding claims, wherein the signal processing means comprises a pulse generator for generating a series of electrical pulses, each of which represents a change in the mechanical forces acting on the periphery of the tyre, as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground.

7. A device according to claim 6, wherein the signal processing means further comprises a counter for counting said electrical pulses.

8. A device according to claim 6 or 7, when the pulse generator comprises a CMOS circuit.

9. A device according to any one of claims 6 to 8,

wherein the signal processing means further comprises an analogue / digital converter, and said pulse counter comprises a shift register.

10. A device according to any one of claims 6 to 9, wherein the signal processing means further comprises a micro-processor for processing the output of the pulse generator and collating data relating to the number of revolutions rotated by the tyre.

11. A device according to claim 1, wherein the signal processing means provides an output representative of a number of revolutions rotated by the tyre.

12. A device according to claims 10 and 11, wherein the signal processing means in use periodically collates data, each collation period corresponding to a plurality of revolutions of the tyre.

13. A device according to any one of the preceding claims, wherein the output signal of the signal processing means includes an identification code unique to the tyre.

14. A device according to any one of the preceding claims, further comprising radio frequency transmitter means for transmitting the output signal of the signal processing means to a remote station.

15. A device according to any one of the preceding claims, further comprising radio frequency receiver means for enabling the device to be interrogated from a remote station.

16. A device according to claims 14 and 15, wherein transmission of the output signal of the signal processing means is activated by interrogation of the device via the radio frequency receiver means from the remote station.

17. A device according to any one of the preceding claims, further comprising pressure sensor means for providing an electrical output signal representative of the pneumatic pressure in the tyre, wherein the output signal of the pressure sensor means is supplied to the signal processing means.

18. A device according to claim 17, wherein said pressure sensor means includes a piezoelectric element.

19. A device according to any one of the preceding

claims, further comprising temperature sensor means for providing an electrical output signal representative of the temperature of the tyre, wherein the output signal of the temperature sensor means is supplied to the signal processing means.

20. A device according to any one of the preceding claims, wherein the device is included in a single transponder unit adapted to be mounted in use adjacent the periphery of the tyre.

21. A system for monitoring mileage of individual tyres of a vehicle, the system comprising a plurality of devices according to any one of the preceding claims, and display means for receiving the output signal of the signal processing means of each said device and displaying mileage travelled by each tyre of the vehicle.

22. A system according to claim 21, wherein the display means comprises a computer.

23. A system according to claim 21 or 22, wherein the display means is remote from the vehicle

24. A method of monitoring mileage of a vehicle tyre, the method comprising:

providing a mechanical transducer adjacent the periphery of a tyre for producing an electrical output representative of mechanical forces acting on the periphery of the tyre adjacent the transducer during rotation thereof; and

detecting changes in the mechanical forces acting on the periphery of the tyre as a result of the periphery of the tyre adjacent the transducer coming into contact with the ground; and

providing an electrical output signal representative of the number of revolutions rotated by the tyre.

25. A method according to claim 24, wherein the step of detecting changes in the mechanical forces acting on the periphery of the tyre comprises generating electrical pulses representative of the changes in mechanical forces, and counting said pulses.

26. A method according to claim 24 or 25, further

comprising the step of periodically collating the output signal representative of the number of revolutions rotated by the tyre, wherein a period of collation corresponds to a plurality of revolutions.

27. A method according to any one of claims 24 to 26, further comprising the step of providing in the output signal an identification code unique to the tyre.

28. A method according to any one of claims 24 to 27, further comprising the step of transmitting the output signal via a radio frequency transmitter to a remote station.

29. A method according to claim 28, further comprising the step of initiating said transmission of said output signal from a remote station via a radio frequency receiver.

30. A method according to any one of claims 24 to 29, further comprising the step of monitoring the pressure in said tyre.

31. A method according to any one of claims 24 to 30, further comprising the step of monitoring the temperature of said tyre.

32. A tyre mileage monitoring device substantially as hereinbefore described with reference to the accompanying drawings.

33. A tyre mileage monitoring system substantially as hereinbefore described with reference to the accompanying drawings.

34. A tyre mileage monitoring method, substantially as hereinbefore described with reference to the accompanying drawings.

(The Search report)

Relevant Technical Fields

(i) UK Cl (Ed.N) G1N (NACNC, NACNN, NAFD10, NAFDR, NAHJA, NAHJD)

(ii) Int Cl (Ed.6) G01C 22/00, 22/02

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE: WPI

Search Examiner
MR G CLARKE

Date of completion of Search
18 DECEMBER 1995

Documents considered relevant following a search in respect of Claims :-
1 to 34

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

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&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2242527 A	(GEC-MARCONI LTD) whole document	
A	GB 1311585	(THE BENDIX CORPN) whole document	
A	EP 0254445 A1	(PHILIP E. GALASKO) whole document	

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/15631

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60C23/04 B60C23/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 - B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 307 044 A (JESSOP JOHN MICHAEL) 14 May 1997 (1997-05-14) page 6, line 1 -page 7, line 9; figures 1,2	1,5
X	US 5 546 070 A (ELLMANN MANFRED ET AL) 13 August 1996 (1996-08-13) column 2, line 17 - line 58; figures 1,2	1
A	US 4 862 486 A (WING J KEITH ET AL) 29 August 1989 (1989-08-29) column 1, line 66 -column 2, line 35; claims 5,6; figures	11

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
27 October 1999	03/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Hageman, L

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/15631

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	"PIEZOELECTRIC POWERED (BATTERYLESS) RADIO FREQUENCY IDENTIFICATION TAG FOR TIRES" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 39, no. 8, 1 August 1996 (1996-08-01), page 245/246 XP000638201 ISSN: 0018-8689 the whole document	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Ir ational Application No
PCT/US 99/15631

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